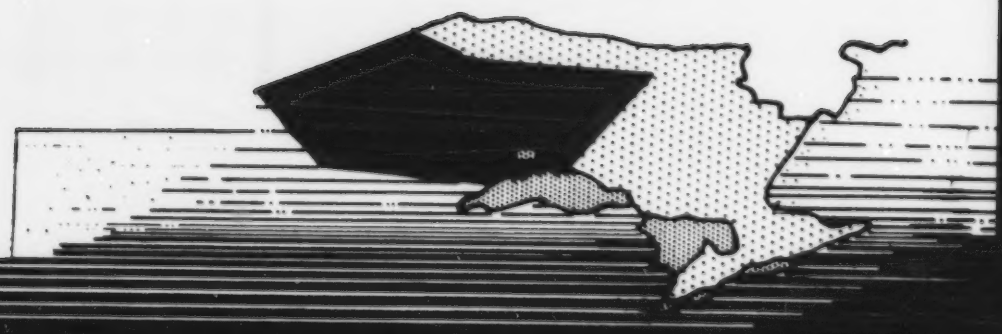

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NORTHWESTERN ONTARIO FOREST TECHNOLOGY DEVELOPMENT UNIT

EVALUATION OF MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSE VARIABLES OF FOUR-YEAR OLD BLACK SPRUCE SEEDLINGS TO PERENNIAL COMPETITION

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EVALUATION OF MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSE VARIABLES OF FOUR-YEAR OLD BLACK SPRUCE SEEDLINGS TO PERENNIAL COMPETITION

BY

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ABSTRACT

Morris, D.M. 1988. Evaluation of morphological and physiological response variables of four-year old black spruce seedlings to perennial vegetation. OMNR, NWOTDU, Technical Report # 23. 16p.

Key Words: Black spruce seedlings, competition dynamics, fisheye lens photography, plantation development, seedling performance.

The overall objective of this paper was to highlight terms used in competition dynamics and evaluate those variables commonly used to describe plantation response to competition.

The example presented was part of a 3-year project funded by COFRDA entitled "Growth response of young plantations to vegetative competition". From preliminary regression analyses, it was determined that simple morphological attributes (ie: total height, CAI, crown dimensions) did not reliably respond to changing competition levels at an early stage of plantation development. Using destructive sampling techniques, additional physiological variables which determine variations in nutrient status, root development, plant structure, and allocation of resources were also tested for their sensitivity to increasing competition stress. The use of relative versus absolute growth response variables was also discussed.

A single independent variable was used for the evaluation of the response variables. An adjusted percent open sky, obtained from fisheye photographs, proved to be the most reliable estimator of incident radiation received by each sampled seedling.

Although foresters commonly use either total height or current height increment as response variables when examining plantation performance, the results from this study demonstrate that these are not reliable for four-year old black spruce plantations. Overall, the most consistent response variable was the square root of the total seedling weight. The coefficients of correlation for the six plantations studied averaged 0.797. It seems apparent that, although minimal morphological changes could be detected, the physiological development of the seedlings responded significantly to changes in competitive stress during early plantation development.

Unfortunately, the forester must be able to make rapid decisions concerning release treatments for his/her plantations. This constraint negates the use of destructive sampling techniques, which are costly and time consuming. Therefore, a simpler measurement which has a high correlation to total seedling weight would be beneficial. To date, a good relationship exists between RCD and total seedling weight. However, this direct relationship is not consistent for all areas studied. Analysis is ongoing to develop a comprehensive competition index which utilizes easily measured variables.

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EVALUATION OF MORPHOLOGICAL AND PHYSIOLOGICAL RESPONSE VARIABLES OF FOUR-YEAR OLD BLACK SPRUCE SEEDLINGS TO PERENNIAL COMPETITION

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INTRODUCTION

An individual in a population of seedlings must become established and gain access to resources necessary for its future growth and development (Ross and Harper 1972). Since plants are immobile, they are forced to compete with their neighbours throughout their life. The term "competition" implies that the supply of environmental resources falls below the combined demands of the plants, and that these resources are shared unequally between plants (Harper 1964). These resources can include light, water, nutrients, and/or physical growing space (Daniels *et al* 1986). Therefore, the total exploitative competitive ability of any organism must consist of two distinct aspects:

(1) competitive effect - which is the ability of an organism to reduce the performance of other organisms, and

(2) competitive response or tolerance - which is the ability of an organism to continue to perform relatively well in the presence of competitors.

(Goldberg and Fleetwood 1987)

In Northwestern Ontario, the competitive response of planted

stock as related to the competitive effect of perennial vegetation is of critical importance. The major investments being made in tree improvement, stock production, site preparation, and planting produce little dividends if follow-up tending receives inadequate attention. Eradicating competition is expensive, necessitating a selective application based on a thorough understanding of the relationship between plantation productivity and competition level. Studies which provide this understanding require both a measure of the level of competition occurring on a site as well as a measure of tree growth. Using regression analysis, the measure of individual tree growth acts as a response variable when compared to varying competition levels.

Since the early 1970's, a wide variety of competition indices have been developed based on measures such as stem diameter (Bella 1971, Hegyi 1974), canopy development (Arney 1972, Ek and Monserud 1974, Howard and Newton 1984), or proximity-based models (Daniels 1976, Wagner 1982, Weiner 1984). The majority of studies have considered tree response to competition in terms of absolute height or basal area. More recently, in attempts to reduce size and environmental influences, researchers have tended to use relative growth measures (Zedaker 1982, Brand 1986). A common thread linking the majority of these studies is the use of easily measured morphological attributes (eg: height, relative height growth). Unfortunately, the sensitivity of such variables to changing competition may not be great enough during the establishment phase of plantation development. Thus, providing little assistance to foresters in making early tending decisions essential to

prevent suppression or mortality of the crop species.

The purpose of this paper is to evaluate the sensitivity of various response variables to changing competition levels in order to provide some insight into the complexities of competition dynamics occurring in young plantations.

EVALUATION OF SEEDLING RESPONSE VARIABLES USED IN THE DEVELOPMENT OF COMPETITION INDICES

The data used for this evaluation were collected in 1987 from six 4-year old black spruce plantations located in the North Central Region of Ontario. Three of these plantations were established with bare-root (1½ + 1½) stock, the other three were established with over-wintered container (paper pot) stock.

Site Descriptions

A wide range of soil textures and FEC site types were selected for each of the stock types. Table 1 summarizes the site descriptions for the six black spruce plantations. On each site, a random sample of 60 subject trees was selected for measurement.

Response Variables Evaluated

After bud set in late August, each seedling was carefully extracted with the root system intact. The data collected from these seedlings can be divided into two major categories. The first being morphological attributes which describe the form and structure of the seedlings (eg: total height, current height increment, crown dimensions). The other category includes those variables which are closely related to the functions and activities of the developing

Table 1. Site descriptions for six black spruce plantations.

Plot #	Sp./ Stock	Soil Profile Hor.	Depth	Text.*	Soil Moist. Regime *	Soil Drain. Class *	Forest Humus Form *	FEC Site Type *	Base Map/ Twp.
			. . cm . .						
1	Sb-cont	Ah	0 - 9	SIC	Moist	Imperfect	HumiFIBRIMOR	S21	497851
		Bt	9 - 35	SICL	(5)	(5)			
		C	35 -	SIL					
2	Sb-cont	Ah	0 - 6	SICL					
		Bm	6 - 20	SCL	Fresh	Well	FibriHUMIMOR	SS7	Dorion
		C	20 - 31	SCL	(2)	(3)			
		-	Bedrock	-					
3	Sb-cont	Ae	0 - 5	L					
		Bf	5 - 19	SL	Fresh	Well	FibriHUMIMOR	S3	498864
		BC	19 - 46	SL	(2)	(3)			
		C	46 -	SL					
4	Sb-br	Ah	0 - 2	L	Fresh	Very Poor	HumiFIBRIMOR	S7	Conmee
		Bm	2 - 13	C	(2)	(7)			
		C	13 -	C					
5	Sb-br	Ah	0 - 1	LS					
		AB	1 - 13	SIS	Moderate	Rapid	FibriHUMIMOR	S1	485903
		Bf	13 - 32	CS	Dry(0)	(2)			
		C	32 -	CS					
6	Sb-br	Ah	0 - 7	L	Moderate	Rapid	FibriHUMIMOR	S3	495873
		Bf	7 - 43	SL	Dry(0)	(2)			
		C	43 -	LS					

* - See "Field Manual for Describing Soils, 3rd Edition" (1985) for a further explanation of these terms.

seedlings. These physiological attributes help to quantify the physiological processes of the seedlings, and thereby provide some estimate of their growth potential (eg: foliage weight - photosynthesis ; root weight - water/nutrient uptake ; stem weight - resource

allocation). Some of these variables can be further subdivided into absolute and relative growth measurements. A complete list of the response variables tested is provided in Table 2.

Table 2. Evaluated response variables from four-year old black spruce seedlings.

Response Variable	Variable Type	Physiological Process Involved	Absolute Measure	Relative Measure	Ease of Field Measurement
Total Height	Morph		*		Simple
Current Height Increment	Morph		*	*	Simple
Crown Volume	Morph		*		Simple
Root Collar Diameter	Morph		*		Simple
# of Buds	Morph		*		Difficult
Needle Spacing	Morph		*		Difficult
Needle Area	Morph		*		Impossible
Total Seedling Weight	Physio	Photosynthesis/Respiration Efficiency	*		Impossible
Foliage Weight	Physio	Photosynthesis	*		Impossible
Current Foliage Weight	Physio	Photosynthesis	*	*	Impossible
Branch Weight	Physio	Resource Allocation	*		Impossible
Stem Weight	Physio	Wood Formation	*		Impossible
Root Weight	Physio	Water/Nutrient Uptake	*		Impossible
1987 Radial Increment	Physio	Wood Formation	*	*	Difficult
Total Stem Volume	Physio	Wood Formation	*	*	Difficult
Needle/Soil Nitrogen Ratio	Physio	Nutrient Assimilation	*		Impossible

All absolute response variables were adjusted using a square root transformation before regression analysis in an attempt to normalize the sample population.

Estimate of Competitive Stress

Vertical fisheye photographs, using a single-lens reflex camera and a 7.5mm fisheye lens, were taken at the base of the seedling leaders. From the photographs, both the area of open sky and area of negligible light (solid) were calculated using a PLANIX 7P planimeter from these photographs. The remaining area between the two extreme light regimes allows for penetration of diffuse light through the developing canopy. From this data, it was determined that the percentage of open sky represented a good estimator of incident radiation received by each seedling and was used in the evaluation of the response variables. An important adjustment to the open sky percentage was made using the following equation:

$$\text{Competitive Stress (CS)} = \frac{1}{(\%\ \text{open} - (\%\ \text{solid} / \%\ \text{diffuse}))} * 100 . \qquad [1]$$

The purpose of this adjustment was to allow for differentiation between photographs having similar open sky percentages, but a greater proportion of diffuse area. In these cases, the net radiation should be greater and the seedling's response variable increased accordingly. The following example should help to illustrate the usefulness of this adjustment.

For Example:

Tree # 1:	Tree # 2:
% open = 30.00	% open = 30.00
% solid = 50.00	% solid = 20.00
% diffuse = 20.00	% diffuse = 50.00
CS = 3.64	CS = 3.38
predicted lower response variable	predicted higher response variable

Another problem exists when attempting to interpret data collected from a natural system. Cannell *et al* (1984) stated that even on uniform sites, genetic, microsite, stock and planting quality (Burdett *et al* 1984), as well as chance factors can often be equally important as competition in determining the performance of individual seedlings. This high variability makes it difficult to confidently determine the competition effects on an individual seedling basis. However, by averaging seedling responses which have similar competitive stress levels and then comparing these mean values, the effects on seedling development caused by competing vegetation can be isolated more effectively.

Therefore, the 60 subject trees per plantation were divided up into ten groups with ascending competitive stress regimes. Each calculated mean had six individual seedling measurements, although some variation was unavoidable due to the random nature of the seedling selection.

Regression Analysis

Using simple linear regression, all transformed response variables were regressed against the calculated competitive stress variable obtained from the fisheye photographs. The resulting coefficients of correlation have been summarized in Table 3 (relative growth variables) and in Table 4 (absolute growth variables).

Table 3. Summary of coefficients of correlation for relative growth variables from four-year old black spruce seedlings.

Response Variable	Variable Type	Plot # 1	2	3	4	5	6
		. . . . . r^2					
Relative Height Increment	Morph	.411	.177	.140	.196	.023	.269
Relative Foliage Production	Physio	.593	.060	.331	.128	.002	.224
Relative Radial Increment	Physio	.391	.001	.346	.234	.259	.022
Relative Stem Volume Increment	Physio	.767	.016	.447	.327	.021	.030

Table 4. Summary of coefficients of correlation for absolute growth variables from four-year old black spruce seedlings.

Response Variable*	Variable Type	Plot # 1	2	3	4	5	6
		. . . . . r^2					
Total Height	Morph	.071	.196	.720	.381	.664	.193
Current Height Increment	Morph	.607	.019	.470	.043	.224	.393
Crown Volume	Morph	.064	.589	.599	.665	.180	.580
Root Collar Diameter	Morph	.486	.709	.877	.534	.828	.867
# of Buds	Morph	.575	.699	.836	.706	.801	.703
Needle Spacing	Morph	.105	.176	.182	.038	.240	.240
Needle Area	Morph	.294	.047	.246	.035	.003	.381
Total Weight	Physio	.547	.775	.893	.742	.871	.952
Total Foliage Weight	Physio	.618	.710	.869	.759	.817	.920
Current Foliage Weight	Physio	.751	.677	.874	.729	.815	.794
Branch Weight	Physio	.456	.776	.888	.705	.801	.865
Stem Weight	Physio	.368	.809	.883	.651	.896	.838
Root Weight	Physio	.339	.475	.938	.696	.838	.856
1987 Radial Increment	Physio	.693	.695	.869	.391	.872	.748
Total Stem Volume	Physio	.444	.666	.883	.512	.882	.837
Needle/Soil Nitrogen Ratio	Physio	.075	.184	.143	.195	.049	.046

* - all response variables were normalized, using a square root transformation, before regression analysis.

Interrelationships between prominent morphological and physiological variables were examined in a correlation matrix and are summarized in Table 5.

Table 5. Correlation matrix illustrating the relationships between various morphological and physiological attributes of four-year old black spruce seedlings.

	Total Height	Current Height Incr.	Root Collar Dia.	# of Buds	Total Seedling Weight	Total Foliage Weight	Current Foliage Weight
	. . . . . r^2						
Total Height	1.000	0.487	0.465	0.351	0.484	0.430	0.428
Curr. Ht. Incr.		1.000	0.281	0.289	0.331	0.321	0.346
Root Collar Dia.			1.000	0.480	0.633	0.571	0.551
Number of Buds				1.000	0.788	0.794	0.811
Total Seedling Weight					1.000	0.957	0.908
Total Foliage Weight						1.000	0.954
Curr. Foliage Weight							1.000

* - these are the average coefficients of correlation for the six plots studied.

GENERAL DISCUSSION AND MANAGEMENT IMPLICATIONS

Comparison of the relative (Table 3) versus the absolute (Table 4) growth responses clearly indicates that the absolute measurements of seedling performance more consistently relate to the current levels of competition. At this early stage of plantation development, very little difference in relative growth rate occurred amongst the sampled seedlings. The absolute growth response variables reflected the

cumulative effects of competition over four growing seasons.

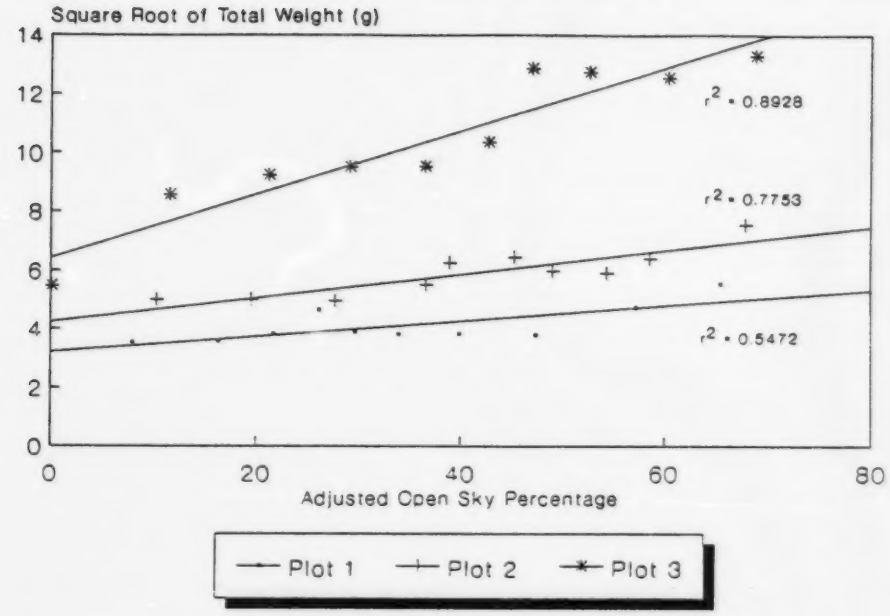
From Table 4, the poorest results were obtained from those response variables which relate to nutrient status and root activity. These variables include needle spacing, needle area, and needle/soil nitrogen ratio (Sutton 1969, Youngberg and Davey 1970). It seems logical that a poor relationship with these variables exists if the seedlings are competing mainly for light, rather than for water and nutrients (Bleasdale 1966). Slightly better correlations occurred on the coarser sites where moisture retention is limited.

It is clear that height growth measurements are not reliable response variables at an early stage (ie: less than 5 years) of plantation development (Table 4). Daniels *et al* (1986) demonstrated that coefficients of correlation with height can be quite small at young ages, but increase over time if competition stress is maintained. Encouraging results for both root collar diameter and number of buds should be noted.

The physiological response variables produce, by far, the most consistent results across the range of sites and stock types (Table 4). It seems apparent that, although minimal morphological differences (ie: total height, CAI) exist at this stage of seedling development, the physiological development already reflects significant differences directly attributable to changes in competitive stress. The three transformed (square root transformation) response variables most consistently related to competitive stress were total seedling weight, total foliage weight, and weight of the current year's foliage.

Averaged over the six areas studied, the square root of the total seedling weight produced the highest coefficient of correlation at 0.797. Figure 1 illustrates the resultant regression lines. There seems to be very little change in sensitivity for the bare root plantations (plots 4, 5, and 6) across the site types. Conversely, the container stock plantations (plots 1, 2, and 3) demonstrate a marked increase in sensitivity as the soil texture became coarser. Sensitivity can be judged by the slope of the regression line.

Foresters commonly use either total height or current height increment as response variables when examining plantation performance. Given the results of this study, it would seem reasonable to determine the status of competitive stress for a given plantation during early development using physiological rather than morphological response variables. Unfortunately, the forester must be able to make rapid decisions concerning release treatments for their plantations. This constraint negates the use of destructive sampling techniques, which are costly and time consuming. Therefore, a simpler measurement which has a high correlation to total seedling weight would be beneficial. Table 5 illustrates that both root collar diameter (r^2 = 0.633) and the number of buds (r^2 = 0.788) have strong relationships to total seedling weight. Although collecting bud counts does not incur great capital investments in equipment, it is a time consuming procedure in the field. Therefore, measurement of the root collar diameter may be the best substitute for total seedling weight. Unfortunately, this direct relationship is not consistent for all areas studied. Analysis is



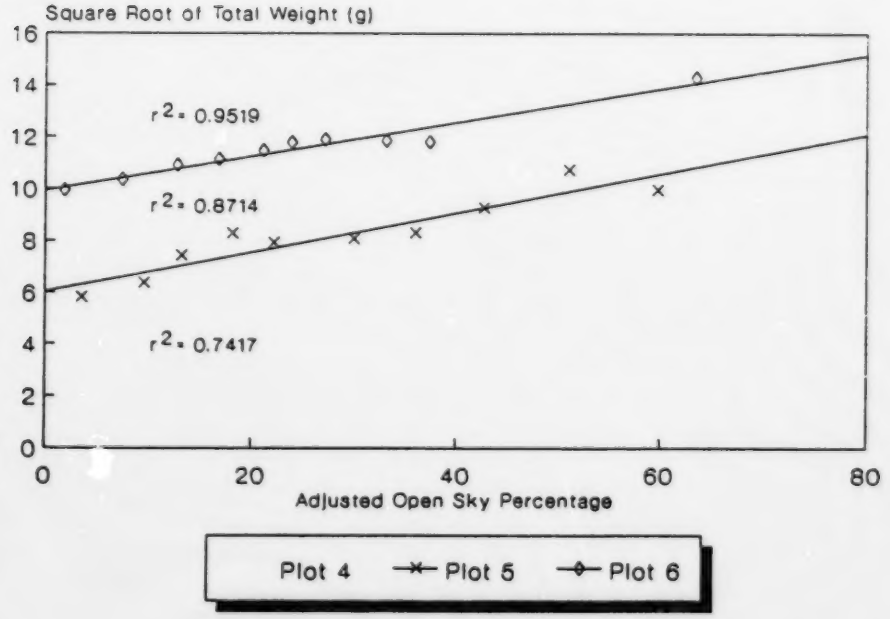


Figure 1. Regression lines for six black spruce plantations depicting changes in total seedling weight (after square root transformation) in response to decreasing competitive stress levels.

currently being carried out to develop a comprehensive index which utilizes easily measured variables for both competitive stress and seedling response.

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